Fermi National Accelerator Laboratory

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CDF

B Production at CDF

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ABSTRACT

In this paper we present results on B production obtained from data taken with the CDF detector at Fermilab, in $p\bar{p}$ collisions at $\sqrt{s} = 1.8$ TeV. b-quark production cross sections using exclusive and inclusive B decay modes are presented and compared with theoretical predictions. We cover recently completed analyses of the 1988-89 data and describe the first preliminary results of the studies of the 1992-93 collider run. Prospects for the near future are also discussed.

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1. INTRODUCTION

B production in hadronic collisions is fundamental for the study of perturbative QCD. The comparison of the experimental data with the QCD predictions provides a necessary check of the ingredients entering the evaluation of hadronic processes, and allows us to determine if they can be used to extrapolate the calculations to higher energies. The b cross section measurement at 1.8 TeV is also an important benchmark to establish the feasibility of CP violation measurements at high energy hadron colliders. Although e^+e^- colliders provide a cleaner environment than hadron colliders for the study of B decays, the rate of $B\bar{B}$ production at the Tevatron is considerably higher than in e^+e^- collisions, and CDF has shown that exclusive B channels can be succesfully reconstructed in a harsh environment. Our data have been taken with the CDF detector [1] which has been recently upgraded. The upgrades relevant for this presentation are the muon chamber upgrade and the employment of a silicon vertex detector (SVX). The original CDF Central Muon detector, which covers the pseudorapidity region $|\eta| < 0.6$, has been complemented by the addition of four layers of drift tubes behind 2 feet of steel. As a result, hadronic punch-through backgrounds to the muon signal have been reduced by a factor of ≈ 10. We have also added layers of drift tubes in the pseudorapidity region of $0.6 < |\eta| < 1.0$ in order to increase our muon coverage. Finally four layers of DC coupled, single sided, silicon detectors with R-ϕ readout have been added around the beam-pipe and provide a very good resolution in the transverse position of primary and secondary vertices. The primary vertex resolution in a typical event is 35 μm, similar to the transverse beam size. The impact parameter resolution is better than 40(15) μm for tracks with $P_T >$ 1 (10) GeV/c.

2. b-QUARK PRODUCTION CROSS SECTION MEASUREMENTS

This presentation will be focused on the measurement of b-quark production cross sections [2]. The CDF measurements from the 1988-89 data are shown in Fig. 1. The curves represent the theoretical predictions based on the next-to-leading order calculation by Nason, Dawson and Ellis [3]. The uncertainty in the predictions arising from choices of the renormalization scale μ, the b-quark mass and the QCD Λ parameter are also shown. The dashed lines correspond to the central value and the upper and lower allowed predictions by using the DFLM structure functions [3]. The dotted lines correspond to similar predictions by using the MT structure functions [4]. Finally the solid lines represent the central value and the upper allowed prediction by using the MRSD0 structure functions [5]. The experimental cross sections are clearly higher than the theoretical predictions at small P_T^b. At larger values of P_T^b, in the region of the inclusive $b \rightarrow$l+X measurements, the data are consistent with the upper extreme of the theoretical band. The b-quark cross section from inclusive J/ψ's has been derived by using the measured integrated J/ψ cross section in the kinematical region $P_T > 6$ GeV/c, $|\eta| \leq 0.5$ and the fraction f_b of J/ψ's originating from B decays. The number of J/ψ events used in the measurement of the cross section was 889 ± 30. The major production mechanisms of the J/ψ's are B decays, direct production through gluon fusion, $\chi \rightarrow J/\psi\gamma$ production and through gluon fragmentation. For this measurement

we derived f_b by reconstructing exclusively χ_c mesons.

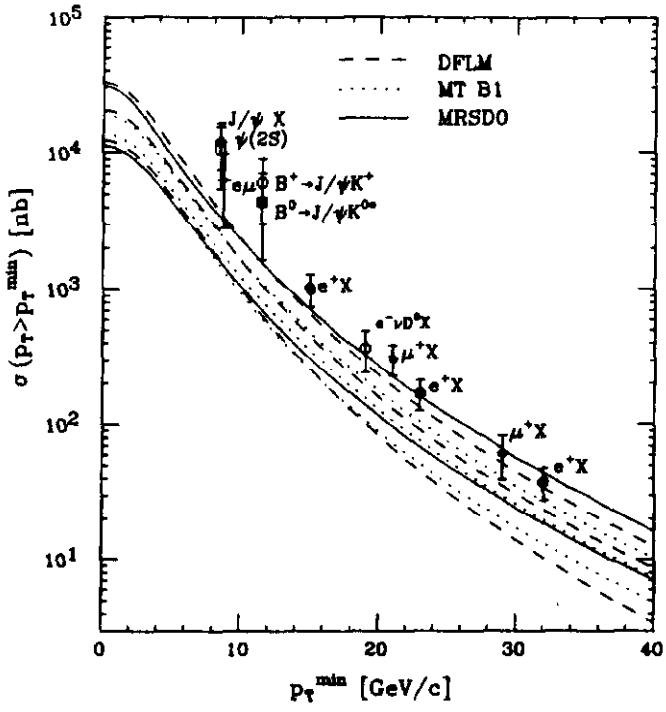

Fig. 1. Integrated b P_T distribution at 1.8 TeV: 1988-89 CDF data versus NLO QCD.

We reconstruct the χ_c mesons through the decay chain $\chi_c \rightarrow J/\psi\gamma$, $J/\psi \rightarrow \mu^+\mu^-$. In the 1988-89 collider run we reconstructed 67 ± 8 χ_c's and we calculated the cross section for the process $p\bar{p} \rightarrow \chi_c X$ to be $\sigma(\chi_c \rightarrow J/\psi\gamma) = 3.2 \pm 0.4(stat) \, ^{+1.2}_{-1.1} \, (syst)$ nb. We also found that the fraction, f_χ, of J/ψ's coming from χ_c decays is $f_\chi = (44.9 \pm 5.5 \, ^{+15.4}_{-14.1})\%$. Assuming that the only processes for J/ψ production are B decays and χ_c decays, the fraction f_b turns out to be $(63 \pm 17)\%$. This value of f_b was used to derive the b-quark production cross section from the inclusive J/ψ sample (see Fig. 1). In the 1992-93 run we have approximately a factor of 5 more J/ψ's per pb^{-1} in comparison with the 1988-89 run. We are also more sensitive now at low P_T J/ψ's. We have approximately 42,000 J/ψ's in 12 pb^{-1} as can be seen in Fig. 2. In the 1992-93 data, by using the SVX we can measure the fraction of J/ψ's coming from B's directly and without any assumptions. From the measurement of the B lifetime with inlusive J/ψ's [6] we have indications that the fraction of J/ψ's coming from B's is lower than the one we assumed in the previous run.

The b-quark production cross section from inclusive $\psi(2S) \rightarrow \mu^+\mu^-$ was based on the $\psi(2S)$ cross section which was measured from (35 ± 8) dimuon events in the 1988-89 run, and it was derived under the assumption that all $\psi(2S)$'s originate from B decays. This measurement will have a considerably improved statistical error from the 1992-93 data. A $\psi(2S)$ mass distribution reconstructed through the decay chain $\psi(2S) \rightarrow J/\psi\pi^+\pi^-$ is shown in Fig. 3 from ≈ 12 pb^{-1} of 1992-93 data. The use of the SVX in the calculation of the $\psi(2S)$ decay length indicates that the $\psi(2S)$ state has a non negligible prompt component.

The b-quark cross section from the eμ sample shown in Fig. 1, is a single-b inclusive cross section based on the observation of a correlated lepton pair that originates from the $b\bar{b}$ produced in the event. This measurement has been based on $\approx$ 1000 lepton pairs.

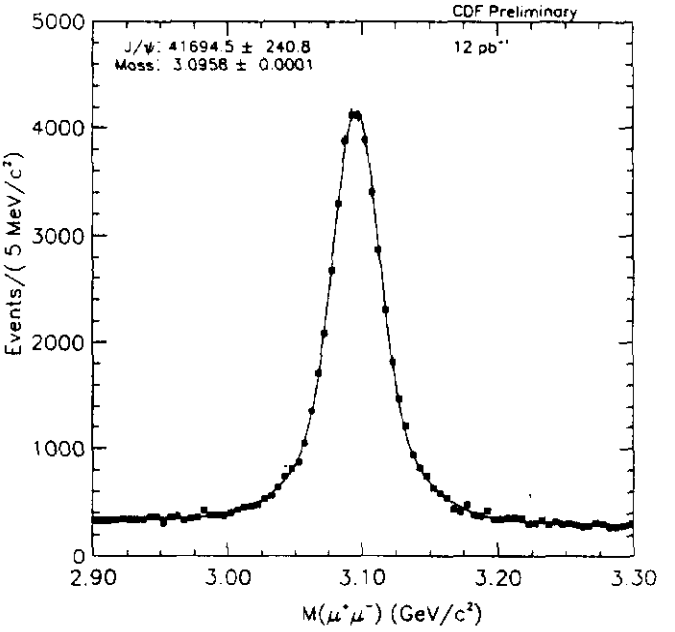

Fig. 2. J/ψ mass spectrum in the dimuon channel from 12 pb^{-1} of the 1992-93 data.

The B meson production cross sections from the exclusive decay channels $B \rightarrow J/\psi K^{\pm}$ and $B \rightarrow J/\psi K^{*}$ were based on 14.1$\pm$4.3 and 9.6$\pm$4.6 events respectively from the 1988-89 data. The corresponding b-quark cross sections were $\sigma^b(P_T > 11.5\ GeV/c,\ |y^b| < 1) = 6.1\pm3.1\ \mu$b and $\sigma^b(P_T > 11.5\ GeV/c, |y^b| < 1) = 4.4\pm2.8\ \mu$b and are shown in Fig. 1. From the 1992-93 data we reconstructed 60$\pm$14 $J/\psi K^{\pm}$ and 24$\pm$13 $J/\psi K^{0*}$ events from 9 pb^{-1} (see Fig. 4). We derived the corresponding b-quark cross sections to be $\sigma^b(P_T^b > 7.2\ GeV/c, |y^b| < 1) = 10.2 \pm 2.4(stat) \pm 3.5(syst)\ \mu$b and $\sigma^b(P_T^b > 8.5\ GeV/c, |y^b| < 1) = 5.3 \pm 2.7(stat) \pm 2.4(syst)\ \mu$b respectively. These new measurements, although statistically consistent with the corresponding ones of the 1988-89 data, they are closer to the theoretical predictions. The reconstruction of these exclusive channels has not used any decay distance or SVX related cuts yet, and therefore the signal to noise ratio is not optimal. Such additional cuts reduce drastically the background as can be seen in Fig. 5.

CDF has also reconstructed B mesons from the decay channel $B^0 \rightarrow J/\psi K_s$. The mass distributions for $K_s \rightarrow \pi^+\pi^-$ and $B^0 \rightarrow J/\psi K_s$ based on 19 pb^{-1} of the 1992-93 data can be seen in Fig. 6. For these distributions it was required that $P_T^{K_s} > 1.5$ GeV/c and $P_T^B > 6.0$ GeV/c.

From the inclusive electron production rate and the associated electron-D^0 production rate in the 1988-89 data we derived the b-quark cross section for four different ranges of P_T^b (see Fig. 1). From the inclusive muon production rate in the same data we derived the b-quark cross section for two different ranges of P_T^b (see Fig. 1).

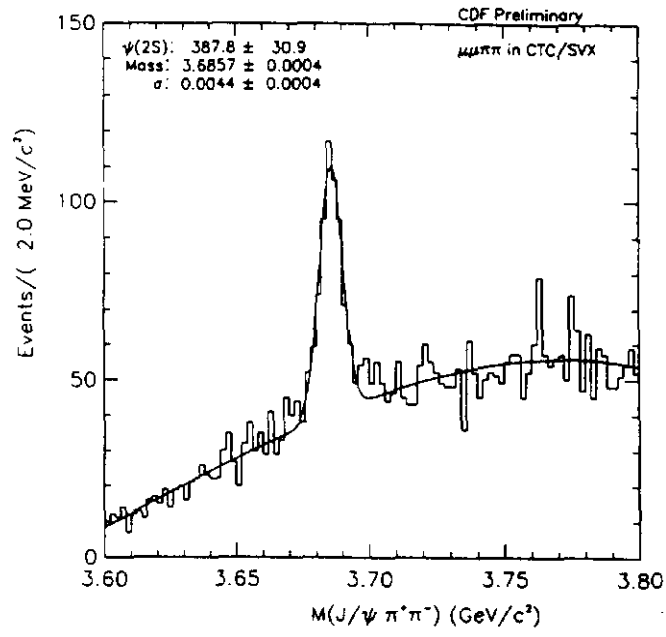

Fig. 3. $\psi(2S)$ mass spectrum in the $\psi(2S) \rightarrow J/\psi\pi^+\pi^-$ channel from $\approx$ 12 pb^{-1} of the 1992-93 data.

The measurements of b-quark production cross sections from the UA1 experiment in $p\bar{p}$ collisions at $\sqrt{s} = 630$ GeV agree much better with the theoretical predictions than the CDF measurements at $\sqrt{s} = 1.8$ TeV do [5]. There have been several attempts to explain the difference such as consideration of higher order corrections to the next-to-leading order theoretical calculation, higher order small-x corrections to the partonic cross sections and modification of the gluon densities [7, 4, 8]. We expect that the analysis of the data set we collected during the 1992-93 run will shed light to the problem.

3. PROSPECTS

By the end of the 1992-93 run ($\approx$ 20 pb^{-1}) we expect to have 75,000 J/ψ's, a few hundred fully reconstructed B mesons in various exclusive J/ψ decay modes, 5 x 10^5 inclusive single leptons from B decays and 5 x 10^3 partially reconstructed events with a lepton and c-hadron in the decay products. Such a sample will lead to a rich B physics program which will become even more interesting after we collect $\approx$ 100 pb^{-1} of data by the end of 1994. This program includes the study of the exclusively reconstructed decays $B_s \rightarrow J/\psi\phi$, $\Lambda_b \rightarrow J/\psi\Lambda$ and $B_c \rightarrow J/\psi\pi$. It also includes the measurement of the average and individual B hadron lifetimes by using the inclusive, semi-exclusive and exclusive J/ψ samples. We also hope to shed more light on the quarkonia production mechanisms by using the J/ψ, $\psi(2S)$, χ_c and Υ samples and by identifying quarkonia produced from B decays by using the SVX. We will produce a whole new set of differential and integrated measurements of b-quark production cross sections and we will study $b\bar{b}$ production through the observation of $b\bar{b}$ correlations. Improved

upper limits of the branching ratios or observation of the rare decay modes $B \rightarrow K\mu\mu$, $B \rightarrow K^*\mu\mu$ are also to be expected. Large statistics of fully reconstructed B decays will allow direct measurements of most of the key ingredients needed to evaluate the capability of an experiment in hadron collisions to perform delicate measurements such as CP violation and B_s mixing.

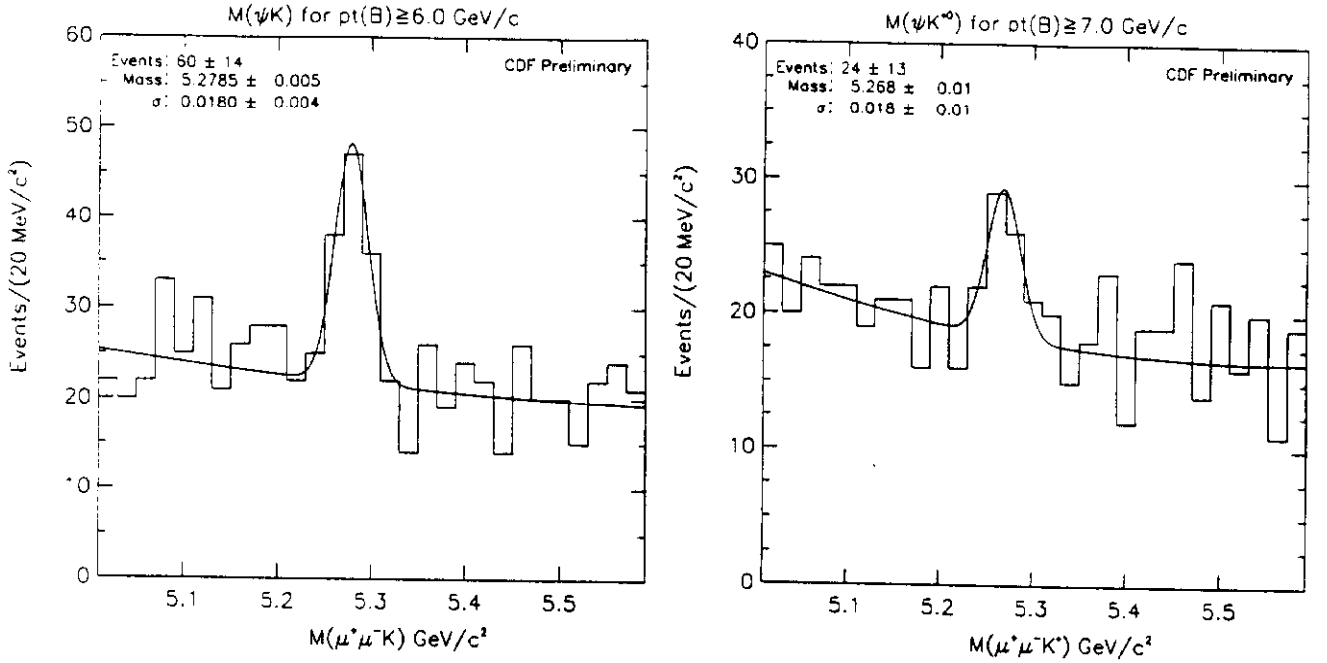

Fig. 4. Reconstructed B mass from the decays $B^{\pm} \rightarrow J/\psi K^{\pm}$ and $B^0 \rightarrow J/\psi K^{0*}$ from 9 pb^{-1} of the 1992-93 data.

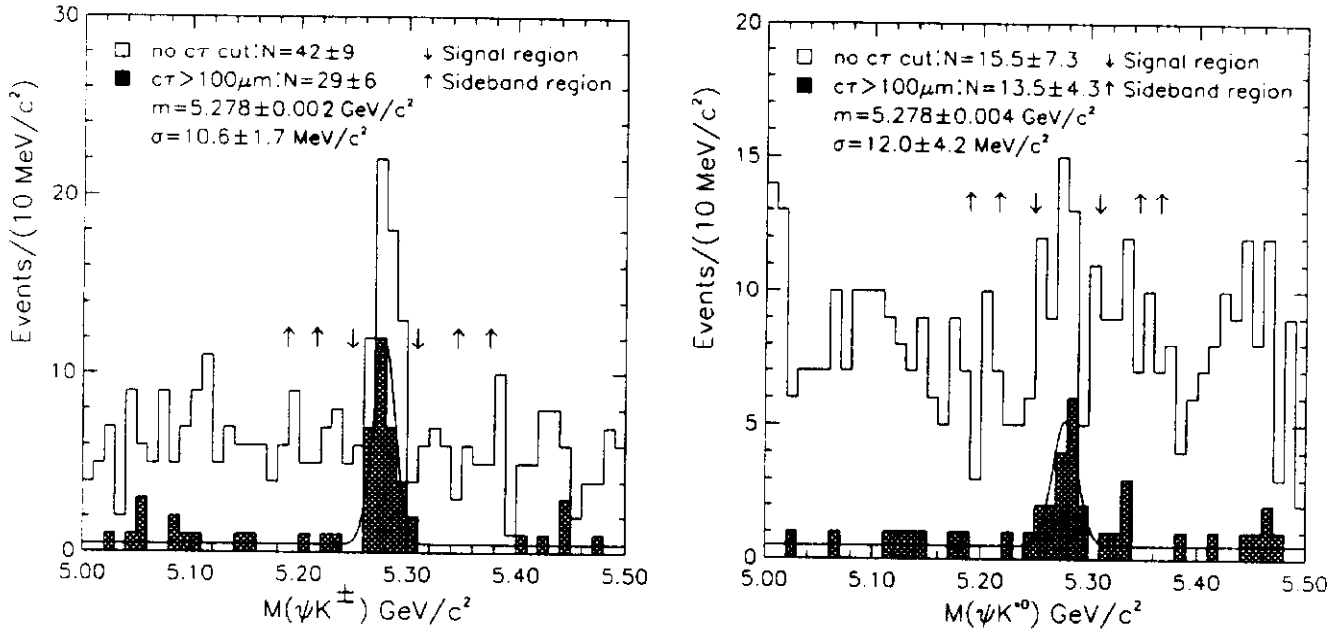

Fig. 5. Reconstructed B mass from the decays $B^{\pm} \rightarrow J/\psi K^{\pm}$ and $B^0 \rightarrow J/\psi K^{0*}$ using the SVX (9 pb^{-1} of the 1992-93 data).

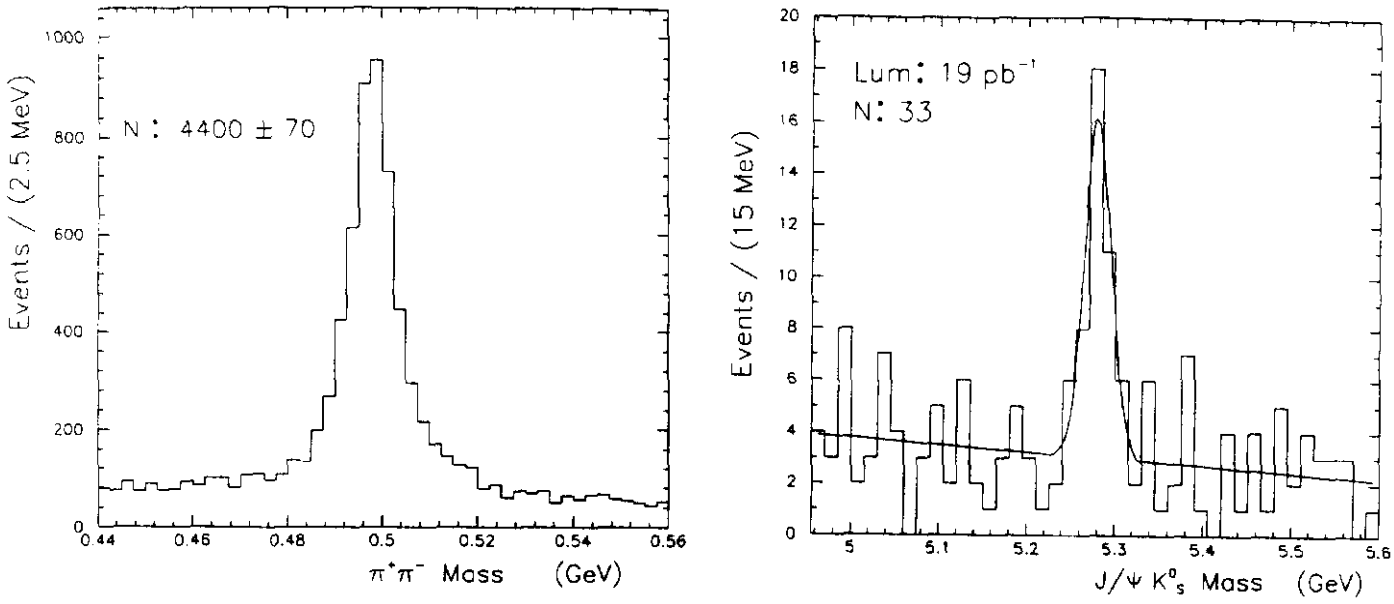

Fig. 6. Reconstructed $K_s \rightarrow \pi^+\pi^-$ mass and $B^0 \rightarrow J/\psi K_s$ mass from 19 pb^{-1} of the 1992-93 data.

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